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Zoological Research

A Training Program for Visual Discrimination Tasks in Monkeys

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Abstract: Go/NoGo tasks are a useful behavioral model in the study of cognitive neurosciences. The present developmental study is aimed at establishing a developmental protocol of Go/NoGo visual-discrimination tasks to investigate more cognitive process. We used two rhesus monkeys to test our procedures. Our results suggested that the monkeys quickly learned Go/NoGo visual-discrimination tasks, and performed NoGo tasks better and easier than Go tasks. Using this visual-discrimination task, we can easily study related cognitive neurosciences.

Key words: Monkey; Go/NoGo model; Visual-discrimination task

建立猕猴 Go/NoGo 视觉分辨任务的方法

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摘要: 在认知神经科学研究中, Go/NoGo 模型是一种非常有效的研究方法。在本试验中, 以两只猕猴为研究对象, 采用 Go/NoGo 模型, 以不同的视觉线索作为刺激来研究相关认知行为。结果表明猕猴能够很快学会 Go/NoGo 视觉分辨任务, 而且对 NoGo 任务的完成要优于对 Go 任务的完成。本实验建立了一种有效的猕猴 Go/NoGo 视觉分辨实验的方法及计算机控制系统, 为进一步记录神经元活动建立了良好的基础。

关键词: 猕猴; Go/NoGo 模型; 视觉分辨任务
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Rhesus monkeys (*Macaca mulatta*) are preferred to other species of monkeys for neuroscience experiments (Ludvig et al, 2001) because they are intelligent and eminently trainable, very resilient and work well on a training schedule. Additionally, their anatomy and physiology are well known and comparable to humans in many respects. The vast majority of behavioural neurophysiology studies in monkeys use techniques originated by Edward Evarts (Evarts, 1966) and remain very similar to those pioneering studies. For example, standard methods include immobilization of the head and a hydraulic drive to move a microelectrode. These techniques are well suited to study many forms of brain function. Go/NoGo tasks are a useful behavioral model in the study of cognitive functions of primates. Combined with electroencephalograms (EEG) and functional magnetic resonance imaging (fMRI) technology, Go/NoGo tasks have been extensively used to study the brain mechanisms underlying the cognitive functions of primates. In the past, a lot of Go/NoGo tasks were de-

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signed, such as delayed Go/NoGo. In this experiment, visual-discrimination tasks were used, which is a new task for examining the way in which information from different visual submodalities is integrated, and studying the associative learning further. In this task, rhesus monkeys learn about the properties of objects that, through associative learning, come to predict and constitute a food reward. In this article, we document the effective training approach for studying neuronal activity further in Go/NoGo visual-discrimination tasks.

1 Materials and Methods

1.1 Subjects and computer control

Two male rhesus monkeys (*Maccaa mulatta*) from the breeding colonies at the Kunming Institute of Zoology (KIZ) were used. Monkeys were 6 – 8 years old and 11 – 17 kg at the beginning of the experiment. They were housed singly under standard conditions (a 12 – h light/dark cycle with light on from 07:00 to 19:00; humidity was 60%, temperature was 21 ± 2℃). The two rhesus monkeys were trained on the Go/NoGo visual-discrimination task while seated in a primate chair, watching a video monitor (LG L5151S) centered at eye level and 80 cm from the monkey. Presentation and sequencing of the stimuli, detection of behavioural responses and delivery of juice reward was computerized (Cortex, Laboratory of Neuropsychology, NIH). The program used generated a data file of critical tasks events (the stimuli numbers, behavioural response latency, trial type, correct/incorrect, reward) with 1ms precision.

During the experiment the monkeys were individually seated in a custom-built primate chair. The door contained an aperture through which the monkey put his hand to press a bar connected to a microswitch. Closure of the microswitch actuated a relay, passing a transistor-transistor logic (TTL) level signal that was detected by an I/O board (Computer boards DIO-24) in a computer. If the behavioural responses were correct, the computer sent a TTL signal to circuitry that opened a solenoid valve, delivering a 1 mL drop of juice though a tube to the monkey's mouth. Fluid intake is about 800 mL (400 mL in am and 400 mL in pm) daily, which was obtained during task performance. Fluids were restricted in the home cage but the large volume of fluid obtained in the task offset this condition. Fruit, nuts and vegetables were given in the laboratory and two meals a day were given in the home cage. All procedures were implemented in accordance with the National Institute of Health Guide for the Care and Use of Laboratory Animals.

1.2 The behavioral task

The Go/NoGo visual discrimination task requires the monkey to distinguish between two categories of stimuli; complex pictures (e.g. Fig. 1a) and simple monochromatic stimuli (e.g. Fig. 1b) (Greenberg et al, 2004). To differentially indicate the identification of these two stimulus categories, the monkey made either a Go response (bar press releases within 500 ms of image presentation) or a NoGo response (bar press releases later than 500 ms). Monkeys initiated trials by pressing the bar, resulting in a 50 ms presentation of a centrally located fixation point, immediately followed by a Go or NoGo stimulus. On Go trials, a complex picture was presented. If the monkey made a wrong response, the Go trial would be repeated until the right

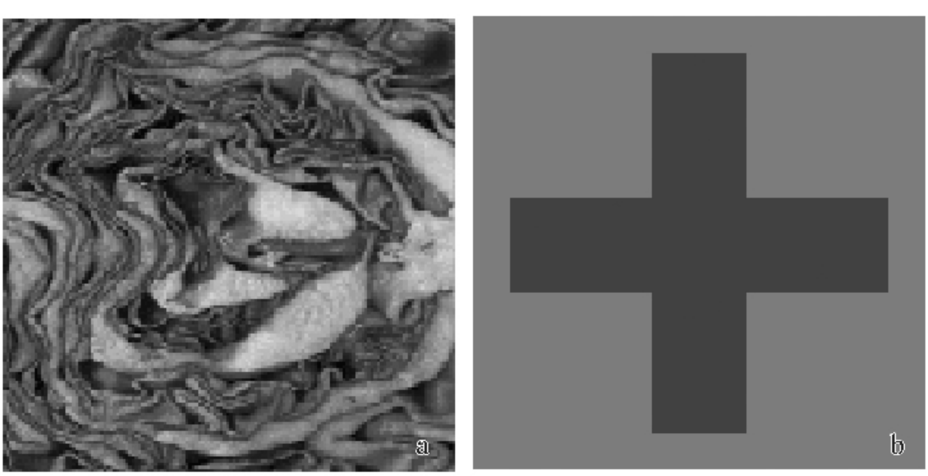

Fig. 1 Two categories of stimuli in the Go/NoGo visual discrimination task, complex pictures (a) and simple monochromatic stimuli (b)

response was made; Go trials were never rewarded. If the stimulus was a NoGo task (simple monochromatic shapes; Komatsu, 1993), the bar press must be maintained for more than 500ms for the delivery of the reward (juice). If the monkey made a wrong response, no reward was delivered, and the next stimulus would be displayed after the fixation point disappeared. Fig. 2 shows this task in detail.

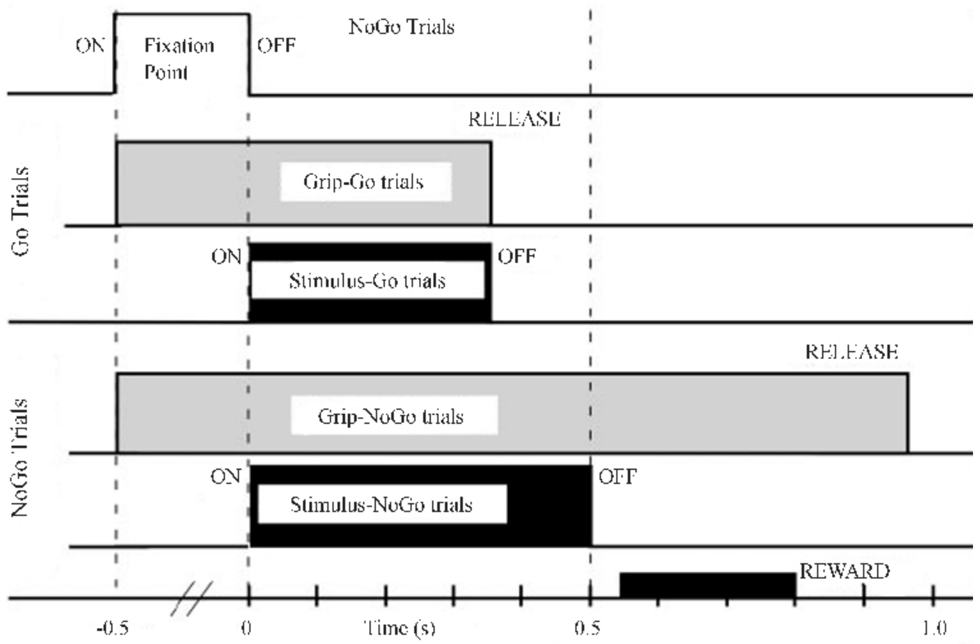

Fig. 2　Task structure: Response (grey rectangles) and stimulus (black rectangles) durations are shown for Go and NoGo trials

Ends of the grey bars for both trial types indicate the monkeys' typical bar release latencies. For both monkeys, bar release latencies on Go trials typically occurred between 300 and 400 ms after stimulus onset, whereas releases on NoGo trials occurred after reward delivery between 700 and 1 100 ms. Reward delivery onset after correctly performed NoGo trials is shown at bottom.

1.3　The monkey training technique monkey

Our research objectives are to create a 'learning set' in the monkeys so that they are able to rapidly learn that a new stimulus is either a Go or NoGo stimulus based on the judgement of stimulus complexity. Such a distinction is similar to that of a categorical judgement and monkeys are able to work with stimulus sets that contain equal numbers of Go and NoGo stimuli with 72 items in each set in total. In order to achieve this objective, we began by starting with a small set of NoGo stimuli ($n = 4$) so that the monkey was rewarded just for maintaining the bar press response while looking at the NoGo stimulus. Subsequently, Go stimuli are introduced and the monkey must learn to release the bar within 500 ms in order to initiate the next trial.

In the early phase of training, monkeys were very sensitive to the absence of a reward and thus we used simple and programmed sequences to reduce the number of times that a particular stimulus was presented. There are more NoGo trials than Go trials in these programmed sequences. For example, the first sequence we used was NoGo, NoGo, NoGo, Go, where the three NoGo cues are the same image. After the monkeys learned this simple task, a random sequence of these stimuli was used. Based on accurate performance, a new stimulus (new NoGo or Go) was added to this sequence. In early training we added only one new Go or NoGo stimulus per session. Thus, the difficulty of the task increased gradually with the number of stimuli during this whole training program.

New stimuli, especially Go stimuli, or random sequences must be used carefully. Many Go trials occurring successively result in a lack of reward and the monkey becomes impatient, and then develops bad habits. Thus early in training the ratio between the number of Go and NoGo trials is carefully titrated so that the monkey is frequently rewarded. After learning the difference between Go and NoGo trials, the monkey learns the appropriate response to new stimuli very quickly (see Results).

As to the introduction of new stimuli, usually a new stimulus was put into the beginning of the programmed sequence. We could increase the times this new stimulus was shown by confining the number of the

stimuli in this programmed sequence. For example, the new stimulus located at the first place in the whole programmed sequence, the first four stimuli in this sequence were displayed during the first 200 or more trials, which enhanced the training times of the new stimulus. After these trials, all stimuli were allowed to display in random or programmed sequence. By this way, the memory for this new stimulus was enhanced.

During the first phase, the monkeys were trained in the laboratory (5.5 m × 4.5 m) in the presence of experiments so that we could watch their behaviour and decide the next step in the training program. During the second phase, the monkey was moved to a specially built testing room (1.8 m × 1.5 m × 1.8 m) in the same laboratory and cameras were used to monitor the monkey's behavior. In this phase, new Go and NoGo stimuli were added based on accurate task performance. Additionally, the monkeys were trained using both alternate random and programmed stimulus sequences to ensure that a balanced set of stimuli were presented.

A fixation point (0.5 deg, red colour) was presented at the beginning of each trial cueing the monkey to the imminent appearance of the Go and NoGo stimuli. Early in training, the fixation point was presented for 50 ms in order to reduce frustration. In this way, the stimulus was presented very quickly after the monkey touched the bar. They did not have to wait for a long time, otherwise they would be impatient. But in this condition, the monkeys' response to the stimuli was not always on purpose. When the monkey did the task well, the fixation point duration was prolonged gradually from 50 ms to 500 ms. Prolonging this duration gradually is very important to avoid frustration. With the prolonged duration, the monkeys have enough time to prepare and judge how to respond to the stimuli. This allowed them to better complete the tasks, resulting in an increase in the correct rate.

1.4 Data analysis

All of the data about the stimuli, behavioural response latency, trial type, correct/incorrect and reward/no reward were recorded by computer with 1 ms precision. These data were transferred to a data analysis spreadsheet (MS Excel) where they were sorted and filtered with the software. Data of the latency about NoGo and Go stimuli were analyzed with paired t-tests. Statistical analysis was conducted using the SPSS 10.0 Statistical Package. Statistical significance was set at the probability level of $P < 0.05$.

The behavioural response latency was recorded as the time at which the monkey released the bar press which was recorded on each trial. Response latencies less than 200 ms were excluded, because this latency was not the real response based on the monkeys' judgement from the visual cue. As we know, the minimal time from the display of the cue to the monkey's decision is 200 ms. Therefore, we concluded these datum were useless, and resulted from the monkey pressing the bar consecutively. The criterion for learning the stimulus type (Go or NoGo) for a new image was a correct behavioral response for a minimum of three consecutive times. Thus, if the monkey correctly responded to a new Go stimulus on its third presentation and for three subsequent presentations, the criterion for learning would be logged as trial 3. In practice, the average number of consecutive correct responses was 5 for new Go stimulus and 1 for new NoGo stimulus.

2 Results

There was significant difference in the trials to criterion between NoGo and Go stimuli ($P = 0.002$), and the difference in the latency of new stimuli between NoGo and Go stimuli was also significant ($P < 0.001$). The latency and the trials to criterion about the Go stimuli decreased gradually, which suggested the monkey learned this task more and more quickly when new stimuli were added. The latency and criterion for each new stimulus the monkey has learned are shown in Fig. 3.

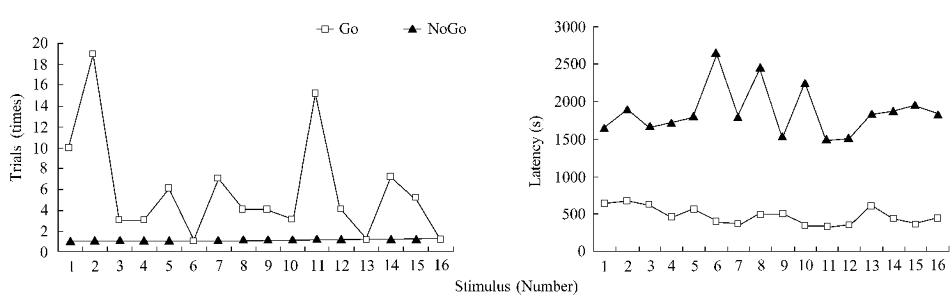

Fig. 3 The latency and criterion of each new stimulus

3 Discussion

The data suggested that the monkeys learned Go/NoGo visual-discrimination tasks quickly. NoGo tasks were finished faster than Go tasks. From our observation, monkeys preferred to deal with new stimulus as NoGo tasks at first, especially in the beginning of this training program, and when they found they made a mistake, they corrected it quickly. Some new stimulus, for example plastic, caused the monkeys a great deal of difficulty; they couldn't remember this type of cue and made many mistakes. There were also some other mistakes resulting from the monkey's curiosity; the Go stimuli were complex and colourful and significantly different. They had never seen them before, so they looked at them much more than 500 ms when these stimuli were displayed in the first few trials, although they knew this type of cue. There existed many other factors which affected the correct rate of new stimulus, including sounds, the monkey's mood and health condition. The monkey must pay much attention to this visual-discrimination task, because 500 ms is very short. Anything which distracted the monkey's attention, decreased the correct rate and criterion. In general, the way for training monkeys to do this visual-discrimination task was effective and efficient.

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江西省中国瘰螈分布的新记录

A New Record of *Paramesotriton chinensis* in Jiangxi Province

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关键词：中国瘰螈；江西省新记录

Key words: *Paramesotriton chinensis*; Jiangxi new record

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江西地区已有两栖动物计 2 目 8 科 38 种（Zhu, 1994），其中有尾类已有记录为 3 种：大鲵（*Andrias davidianus*）、东方蝾螈（*Cynops orientalis*）和肥螈（*Paehytriton brevipes*）。最近笔者在江西永新县深远山自然保护区陆生脊椎动物调查中，发现了蝾螈科（Salamandridae）瘰螈属（*Paramesotrlton*）一种有尾类动物，为江西省分布的新记录。现报道如下，作为该物种地理分布的资料参考。

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1 采集时间和地点

中国瘰螈[*Paramesotriton chinensis*(Gary,1895)]标本由宋玉赞采集于 2006 年 5 月 17 日江西省永新县深远山自然保护区船坪附近小溪,海拔 352—576 m,地理坐标为 26°45.1′N,114°10.4′E。此批标本共有 8 个,其编号为 JGS2006051701—JGS2006051708,现保存于江西井冈山国家级自然保护区管理局野生动物保护研究所。

2 主要形态特征

该螈个体较大,雄性全长 143 mm,雌性为 162 mm。头部扁平,头长大于头宽;唇褶明显。皮肤粗糙,有大的瘰粒:头两侧各有一条腺质脊棱,背面瘰粒分布均匀。背两侧脊棱较低平,背嵴棱明显。尾短于头体长,雄性尾鳍高起。体腹面从吻下到腹部有大小不一的橘红色斑,稀疏而显著(Tian & Jiang,1986);体背和体侧为黑褐色。中国瘰螈永新地区标本的量度见表 1。

表 1 中国瘰螈永新地区标本的量度

Tab. 1 Specimen measurements of *Paramesotriton chinensis* in Yongxin area, Jiangxi Province

特征 Characteristics	量度 Measurement(mm) ♂($n=5$)	量度 Measurement(mm) ♀($n=3$)
全长 Full length(body and tail)	143 ± 8	162 ± 7
体长 Length of body	76 ± 11	82 ± 5
头长 Length of brain	21 ± 2	23 ± 1
头宽 Width of brain	15 ± 1.83	16 ± 1
尾长 Length of tail	67 ± 9	80 ± 6
鼻间距 Internasal distance	4.02 ± 0.16	4.13 ± 0.11
眼间距 Intereye distance	9.01 ± 0.78	10.11 ± 0.13
前肢长 Length of forelegs	23 ± 3.06	27 ± 1.73
后肢长 Length of hind legs	24 ± 2.81	28 ± 0.19
眼径 Width of eye	4.23 ± 0.27	4.67 ± 0.17
吻长 Width of mouth	8.01 ± 0.36	8.51 ± 0.24

3 与其他地区中国瘰螈形态的差异

与浙江、安徽、湖南、广东、广西和重庆标本(Xie et al,2004;Fei,1999)比较,永新标本个体较大;尾下纵行斑为显著的橘红色;体腹面从吻下开始就有橘红色斑块;吻显著长于眼径;眼间距约 2 倍于眼径。

4 生态习性

生活在小的流溪中,水面宽 5—10 m,栖息水位较浅,为 0.5—1 m。水栖性强,越冬后几乎就生活在水中。本次采集量大、偶然捕获率高,说明本地区该物种的种群数量较为丰富,为优势物种。

5 保护现状

该螈未列入《中国濒危动物红皮书·两栖爬行类》(Zhao,1998)和《国家重点保护野生动物名录》。由于有一定经济价值,被捕捉作观赏和药用,种群数量会有所下降。

6 分 布

该螈已知在浙江、安徽、湖南、福建、广东、广西、和重庆等地有分布(Xie et al,2004;Fei,1999);而本报道为该物种在江西的分布点。该分布点的发现对该物种的动物地理学研究有一定意义。

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